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HOME AND FARM PREPARATION OF VINEGAR[1]

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FRUIT UNSUITABLE for sale fresh or for canning or drying, and honey too dark in color or otherwise unsatisfactory for the table, can often be made into vinegar for home use or for local sale.

This circular discusses the principles involved and describes simple methods of preparing vinegar in the home and on the farm. The directions given do not include instructions for the large-scale manufacture of vinegar by the quick process, for this requires costly equipment than can be operated successfully only by experienced and properly trained persons. The fundamental principles, however, are the same, whether vinegar is made in the home, on the farm, or in the factory.

NATURE AND ORIGIN OF VINEGAR

Vinegar may be defined as a condiment prepared from various sugary or starchy materials by alcoholic and subsequent acetic fermentation. It consists principally of a dilute solution of acetic acid in water, but also contains flavoring and coloring or extracted matter, fixed fruit acids, and salts, varying according to its origin. These additional substances give to vinegar its distinctive quality.

Vinegars are classified according to the material from which they are made and the methods of manufacture. Thus, there are cider, wine, peach, pear, orange and other fruit vinegars, malt vinegar prepared from sprouted cereal grains, sugar vinegar, and honey vinegar. Distilled vinegar, often called "white vinegar" and sometimes erroneously "white wine vinegar," is made by the acetic fermentation of dilute distilled alcohol.

STATE AND FEDERAL REGULATIONS[4]

If vinegar is to be offered for sale it has to meet the requirements of the following definitions and standards:[5]

1. Vinegar, cider vinegar, apple vinegar is the product made by the alcoholic and subse-

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[3] Associate Professor of Fruit Technology and Associate Chemist in the Experiment Station.
[4] It is no longer necessary to obtain a permit from the Federal Bureau of Industrial Alcohol in order to manufacture vinegar.
[5] State of California Department of Public Health. California pure foods and drugs acts. Rules and regulations and standards of purity and decisions rendered by U. S. Department of Agriculture, p. 106, 109. Sacramento. 1927.

quent acetous fermentations of the juice of apples, and contains in one hundred (100) cubic centimeters (20° C) not less than four (4) grams of acetic acid.

2. Wine vinegar, grape vinegar, is the product made by the alcoholic and subsequent acetous fermentations of the juice of grapes, and contains in one hundred (100) cubic centimeters (20° C), not less than four (4) grams of acetic acid, not less than 1 gram of grape solids, and not less than 0.13 gram of grape ash.

3. Malt vinegar is the product made by the alcoholic and subsequent acetous fermentations, without distillation, of an infusion of barley malt or cereals whose starch has been converted by malt, and contains in one hundred (100) cubic centimeters (20° C), not less than four (4) grams of acetic acid.

No definite standards except for acid content have been set for other fruit vinegars. Such vinegars must be made from the juice of the fruit designated on the label and must contain at least 4 grams of acetic acid per 100 cc (cubic centimeters).

Vinegar manufacturers and dealers generally use the term "grain strength" rather than per cent acetic acid. Thus, a vinegar containing 4 grams of acid per 100 cc (approximately 4 per cent acid) is spoken of as a vinegar of 40-grain strength; that is per cent acid times ten gives the strength of the vinegar in grains.

For home consumption it is not essential that the vinegar be prepared to meet these standards, and a mixture of various fruits can be used.

Vinegar offered for sale, as previously stated, must contain at least 4 grams of acetic acid per 100 cc; must be wholesome, that is made from sound, edible fruit; and must be properly labeled.[6]

PRINCIPLES OF VINEGAR MANUFACTURE

The manufacture of vinegar requires two fermentation processes. The first transforms the sugar of the fruit or juice into alcohol. This is brought about by yeast, a microscopic organism of the plant kingdom. The second changes the alcohol into acetic acid and is caused by vinegar bacteria.

The alcoholic fermentation must be complete before the acetic or "vinegar" fermentation is allowed to start, otherwise the yeast fermentation will be stopped by the acetic acid and unfermented sugar will remain in the vinegar. Such a condition results in weak vinegars of poor quality and low yields of acetic acid.

The chemical reactions involved are as follows:

$$\underset{\text{fermentable sugar}}{C_6H_{12}O_6} \xrightarrow{\text{yeast}} \underset{\text{carbon dioxide}}{2CO_2} + \underset{\text{alcohol}}{2C_2H_5OH}$$

$$\underset{\text{alcohol}}{C_2H_5OH} + \underset{\substack{\text{oxygen}\\\text{of air}}}{O_2} \xrightarrow{\text{vinegar bacteria}} \underset{\text{acetic acid}}{CH_3COOH} + \underset{\text{water}}{H_2O}$$

One of the chief causes of failure has been the overlooking of the fact that vinegar making involves these two very distinct fermentations and that the first must be completed before the second begins.

[6] Anyone contemplating the manufacture of vinegar for sale should write to the State Food and Drug Laboratory, State Board of Health, University of California, Berkeley, for regulations governing labeling of food products. See also footnote 4.

Alcoholic Fermentation.—To secure prompt and rapid fermentation a desirable type of yeast must be present and conditions must be made favorable to its growth and activity. Yeast requires certain nutrient salts in addition to sugar. These are normally found in fruit juices, but they are lacking in diluted honey and pure sugar solutions. A favorable temperature of 75° to 80° F should be maintained during fermentation. At temperatures above 100° F fermentation becomes abnormal and ceases at 105°.

Alcoholic fermentation will occur naturally with the growth and activity of yeasts present on the fruits themselves. Such a fermentation is, however, unreliable, usually wasteful of sugar, and the resulting vinegars are of varying and uncertain quality. It is best, therefore, to add a "starter." Ordinary compressed yeast, obtainable almost everywhere, is a satisfactory starter for the alcoholic fermentation. The flavor of the resulting vinegar, however, can be improved by using a culture of a pure wine yeast such as that referred to on page 12, which has been especially cultivated for vinegar production.

With the exception of aeration at the start, air is not necessary during alcoholic fermentation and is especially objectionable in the later stages, for it may cause premature infection with vinegar bacteria and loss of alcohol owing to the growth of "wine flowers." The alcoholic fermentation, therefore, should be conducted in containers in which the juice is not unduly exposed to the air. A barrel lying horizontally with the bunghole covered with screen or plugged with cotton is satisfactory; or for small quantities, a large bottle plugged with cotton. The container must not be sealed airtight or it will burst from gas pressure. Room for frothing must also be allowed.

The juice is allowed to ferment until practically all the sugar is converted into alcohol and carbonic acid gas. If conditions are favorable the process will be complete in about 3 weeks or less. The progress of the fermentation may be watched by means of a Balling or Brix sugar tester or hydrometer. This instrument indicates approximately the amount of sugar present. The hydrometer may be obtained from any chemical supply house direct, or through a drug store, for about 75 cents. Brix and Balling hydrometers indicate approximate per cent of sugar. An instrument reading from 0° to 70° Balling or Brix should be specified. A tall glass or tin cylinder will also be needed. To make the test pour the juice into the cylinder, insert the hydrometer, and read the Balling degree (approximate per cent of sugar) indicated at the surface of the liquid (fig. 1).

After alcoholic fermentation is complete the juice should be freed from yeast, pulp, and other sediment by settling and racking (drawing off) or by filtering before beginning the acetic fermentation. If left in the juice the sediment may give a bad flavor and interfere with acetic fermentation and clearing of the vinegar.

Acetic Fermentation.—The formation of acetic acid is due to the oxidation of alcohol by the oxygen of the air and is induced by vinegar bacteria. These bacteria, unlike the alcohol-producing yeasts, require a generous supply of oxygen for their growth and activity and for the conversion of alcohol into acetic acid. The number of acetic bacteria usually present in fermented juice is small and they are often of an undesirable or inactive type. Therefore a suitable starter should be added to supply the proper kind of bacteria and to make

conditions favorable to their growth and activity. The best means of preventing the growth of undesirable organisms is to acidify the fermented juice *after alcoholic fermentation is complete* by adding strong, unpasteurized vinegar. The addition of such vinegar also inoculates the fermented juice heavily with vinegar bacteria. The proportion is one volume of unpasteurized vinegar to three to five volumes of fermented juice. Acidification in this manner is desirable also when a pure culture of acetic acid bacteria is used.

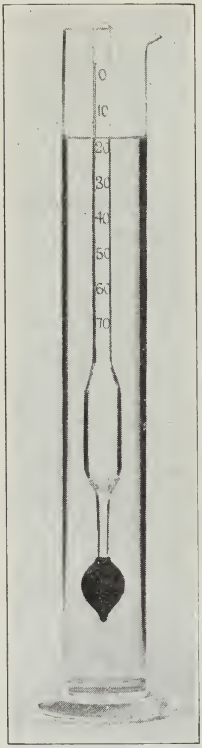

Fig. 1.—Balling (or Brix) hydrometer and cylinder. Make reading at the general surface level, not at the top of the liquid adhering to the stem.

The vinegar bacteria grow in the liquid and on the surface exposed to the air where they may form a smooth, grayish-white, glistening gelatinous film. The film does not always form, for some species of vinegar bacteria grow only in the liquid and not on the surface. If the film is undisturbed the liquid remains fairly clear until converted into vinegar. If the bacterial film is broken it sinks to the bottom where it grows in the absence of air and exhausts the nutrients of the solution without producing acetic acid. It should therefore not be disturbed. The rate of conversion of alcohol into acetic acid depends on the activity of the acetic acid bacteria, the temperature, and the amount of surface exposed per unit volume. At a favorable temperature, about 80° to 85° F, the limiting factor is the area of surface exposed. The time required in the commonly used variations of the slow process is about 3 months. In the generator process where the surface exposed to air is large, the time for the fermentation is shortened to a few days. This method, as previously stated, is not practicable for home and average farm-scale operations.

After the completion of the acetic fermentation the vinegar should not be exposed to the air, because the acetic acid bacteria will then oxidize the acetic acid into carbonic acid gas and water and thus the vinegar will be reduced rather quickly to a worthless condition. To prevent this undesirable change it is necessary to keep the finished vinegar tightly sealed in completely filled containers. It is sometimes desirable, also, to pasteurize the vinegar in the manner described later.

Yields of Alcohol and Acetic Acid.—Theoretically, every 100 parts of sugar should yield about 51 parts of alcohol and about 49 parts of carbon dioxide gas by weight. In practice, about 45 to 47 parts of alcohol are obtained, since some of the sugar is used as food by the yeast, or is lost in the production of other substances. In the acetic fermentation, 100 parts of alcohol should yield about 130 parts of acetic acid. Actually, because of evaporation and other losses, less than 120 parts are obtained. Hence by starting with 100 parts of sugar, it is possible, under very favorable conditions to obtain from 50 to 55 parts of acetic acid. Therefore, to prepare a vinegar of the legal minimum acid content of 4 grams per 100 cc (4 per cent), or of 40-grain strength, it is necessary to use a juice that contains at least 8 per cent of sugar.

DIRECTIONS FOR MAKING VINEGAR IN THE HOME

Vinegar may be prepared on a small scale in the kitchen from many varieties of fruits and from waste peels and cores obtained in the preparation of fruits for canning or preserving. Honey may also be used.

Preparation of the Juice.—Pass apples, pears, or pitted peaches through a small food grinder (fig. 2), using the coarse knife. Berries, grapes, and other soft fruits may be crushed by the hand or with a potato masher, without the use of a food chopper. Peels and cores may be mixed with an equal volume of water and boiled until soft. Honey should be diluted with 1 part fruit juice and 4 parts water—the fruit juice being necessary to furnish yeast food.

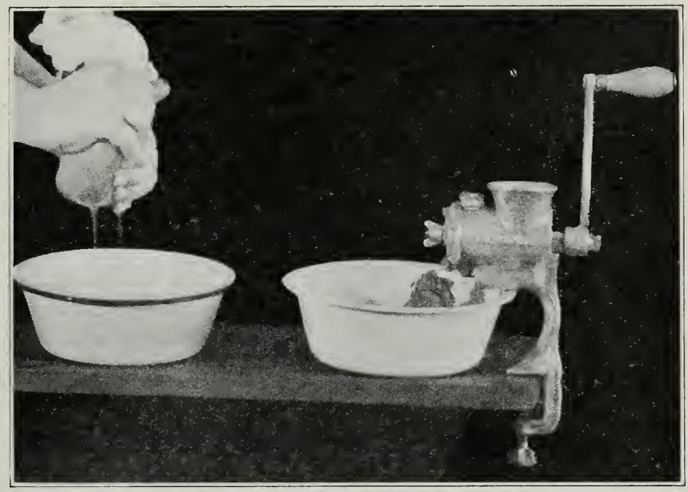

Fig. 2.—At right, small food grinder suitable for preparing firm fruits for pressing. At left, pressing the ground or crushed fruit.

Press the crushed fruit or the boiled peels and cores through a double thickness of cheesecloth. To the dilute juice from peels and cores add ¼ pound of sugar per quart. Sugar should not be added to the juices of other ripe fruits or to honey.

Yeast Fermentation.—To each quart of cooled juice add about ¼ cake of fresh yeast, which should be well broken up and thoroughly mixed with the juice. The juice must not be above 90° F when the yeast is added. Allow it to stand in a stone or glass jar (fig. 3) with the lid removed and with the jar covered with a cloth until gas formation ceases; or, allow the juice to ferment in a gallon jug or bottle of any suitable size and plugged with cotton or covered with cloth. The fermentation usually requires 2 weeks.

Vinegar Fermentation.—When gas formation has ceased, separate the fermented liquid from the sediment. To each quart of this liquid add about half a pint of good unpasteurized vinegar. Cover the jar or bottle with a cloth to exclude insects and allow it to stand in a warm place until the vinegar is strong enough to use. Separate it from the "mother of vinegar" and sediment, bottle it, and cork tightly. Mother of vinegar is the white, rubbery mass of vinegar bacteria that often forms in vinegar.

Never add vinegar to the fresh juice because it interferes with the yeast fermentation and will result in a weak vinegar. The vinegar must not be added until the yeast fermentation is complete. It will then cause the vinegar fermentation to proceed rapidly and will prevent the molding or spoiling of the fermented liquid.

Vinegar is corrosive. Do not use copper, zinc, or iron utensils in handling it. *Galvanized ware is extremely dangerous to use, for the zinc coating dissolves and makes the juice or vinegar very poisonous.*

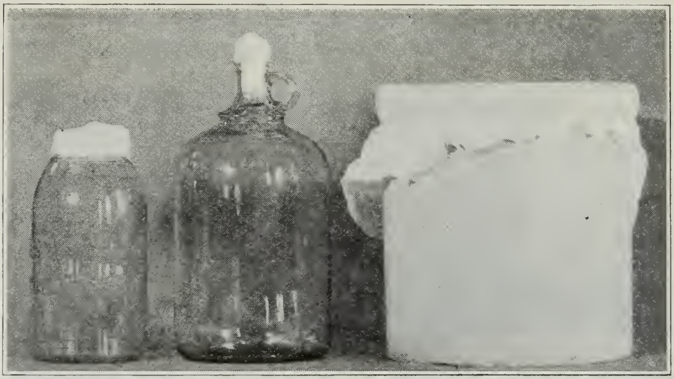

Fig. 3.—Vessels suitable for fermentation and acetification operations in the home. Large fruit jar, 1-gallon bottle, and stoneware crock.

DIRECTIONS FOR MAKING VINEGAR ON THE FARM

Cleanliness.—Too often, failure and poor results in vinegar making are traceable to lack of cleanliness in and about the factory. Dirty press cloths, press racks, pumps and other dirty, moldy equipment infect the juice with molds, wild yeast and harmful bacteria; these cause unsatisfactory fermentation and impart disagreeable tastes and odors to the product. Equipment should be kept clean and dry. Press cloths and press racks should be washed frequently and kept dry between periods of use. Boxes, floors, pumps, filters, crushers, and other equipment or fixtures coming in contact with the fruit, juice, or vinegar, should be washed frequently and maintained in a clean and sweet condition. A concrete floor in the pressing rooms is almost a necessity. It can be washed readily and, unlike wood, is not apt to become sour and moldy.

Raw Materials.—Apples and grapes are used much more commonly than other fruits for vinegar making, although oranges, pears, juicy varieties of plums, peaches, and unsulfured dried fruits such as prunes and raisins are suitable. The peels and cores from apple dehydraters are used in large quantities in vinegar making. All fruit used for vinegar should be sound and clean. Apples should not be overripe and mealy, because they are then difficult to press and the flavor is poor. Pears should be firm-ripe, and even on the hard-ripe side of maturity; if soft-ripe, it is impossible to press them. Oranges should give juice of at least 12° Balling or Brix and should be ripe enough to yield juice free of bitter taste. Low-grade honey if not of very disagreeable flavor or odor can be used successfully for vinegar making.

Directions for preparing the fruits and honey for fermentation follow.

Washing and Sorting Fruits.—All rotten and wormy fruit should be sorted out and discarded. Apples and pears usually require washing to remove mold and rot accumulated by contact with rotten fruit. A shallow wooden vat or trough can be used for soaking and scrubbing the fruit, and large screen trays for rinsing and draining. In large factories soaking is accomplished by passing the fruit through a long sluiceway of running water, followed by vigorous spraying.

Most apple and pear trees are now heavily sprayed with lead arsenate or other poisonous spray to control the codling moth. Dangerous amounts of spray residue are usually adhering to the surface of the fruit, and pure food and drug regulations require that these be removed. This is best done by treatment with dilute acid or alkali, since it would be impracticable to wipe every individual fruit with a cloth to remove the spray residue.[7] The acid treatment is preferred because the acid removes the lead much more effectively than does the alkali. Either the hydrochloric acid or soda ash[8] method may be used in washing the fruit for vinegar making.

Dissolve 4 pounds each of soda ash (sodium carbonate) and common salt in 12½ gallons of water. Maintain the temperature at about 100° F. Pass the apples or pears through this solution, agitating gently. Allow the fruit to remain in the solution at least 5 minutes, but not more than 10 minutes. Rinse with fresh water.

As an alternative method prepare a solution of 3 gallons of commercial hydrochloric acid (muriatic acid) in 100 gallons of water. Use paraffined wooden equipment because the acid is very corrosive and injurious to metal, cloth, and the skin. In case of accident wash the skin at once with water and apply baking soda; if spilled on cloth apply baking soda at once. Agitate the fruit in the solution 4 to 5 minutes; remove; rinse thoroughly and drain. Use wooden slat trays, not metal screens, for draining.

Crushing.—The fruit must be thoroughly crushed before pressing. For farm use the crusher usually is of the "apple grater" type. This consists of a short, horizontal solid steel cylinder equipped with short knives, and a set of stationary knives toward which the horizontal cylinder rapidly revolves. The fruit is caught between the revolving and the stationary knives and thereby coarsely shredded. Commercial plants now use the hammer-mill-type crusher. These crushers are suitable for all except stone fruits.

Oranges should be very coarsely ground; if finely ground too much oil is obtained from the skins and an excessive amount of gummy substances from the peel and rag. It is best to extract the juice by burring where this can be done economically.

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[7] For a full discussion and description of the removal of spray residues see:

Diehl, H. C., *et al.* Removal of spray residue from apples and pears in the Pacific Northwest. U. S. Dept. Agr. Cir. 59:1–17. 1929.

Robinson, R. H., and H. Hartman. Progress report on the removal of spray residue from apples and pears. Oregon Agr. Exp. Sta. Bul. 226:1–46. 1927.

Streeter, L. R., and S. W. Harman. Spray residues. New York (Geneva) Agr. Exp. Sta. Bul. 579:1–12. 1929.

[8] The soda ash or hydrochloric acid can be purchased from any chemical supply house, or through local dealers in spray materials. The commercial grades, not the chemically pure substances, should be specified.

Grapes and stone fruits, such as plums and peaches, may be crushed in a roller grape crusher of the type commonly used on many farms. This consists of two horizontally placed, fluted metal or wooden rollers, that revolve rapidly toward each other like a clothes wringer. For stone fruits the rollers must be set rather far apart to avoid breaking the pits. For grapes they are set more closely together so that all of the berries are broken.

Usually the crusher and the press are combined in a single piece of equipment (figs. 4 and 5).

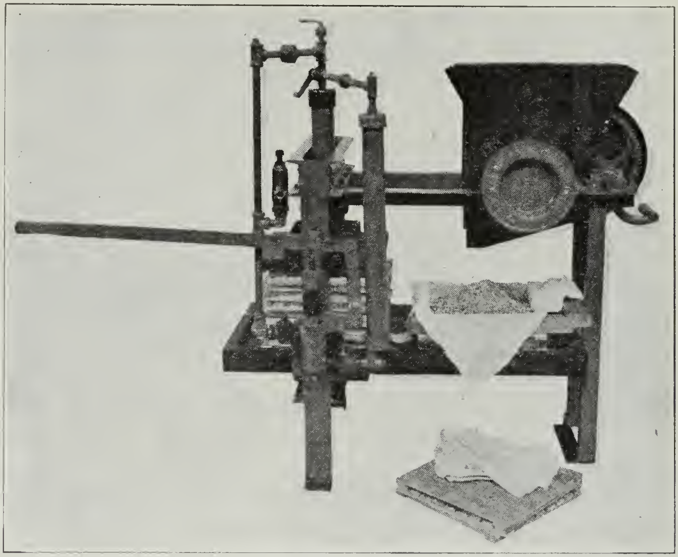

Fig. 4.—Hand-operated crusher and press suitable for farm-scale production of juice. (Courtesy of Hydraulic Press Manufacturing Co.)

Pressing.—The three common types of presses are rack-and-cloth, basket, and continuous screw expeller. For most fruits the rack-and-cloth type is to be preferred because it gives clearer juice than the others, a higher yield than the basket type, and less pulp and sediment than the continuous press. In using the rack-and-cloth press, the crushed fruit is spread on heavy cotton or burlap press cloths in a frame to a depth of about 2½ to 3 inches, and the edges of the cloth are folded to the center. Wooden racks are placed between the cloths containing the crushed fruit. Pressure is usually applied by a hydraulic pump operated by motor, though hand-operated pumps are also available. Heavy oil is used in the pressure system. The pump should be equipped with a pressure release valve to prevent bursting of the cloths by excessive pressure. A power-driven rack-and-cloth press is shown in figure 5.

Grapes and other soft and very juicy fruits can be pressed in a basket press, such as that illustrated in figure 6. For grapes the press need not be lined; but for other fruits, owing to their slimy consistency when crushed, tack burlap around the inside of the basket or use press cloths and racks as previously described for the rack-and-cloth press. Pomegranates are pressed whole in

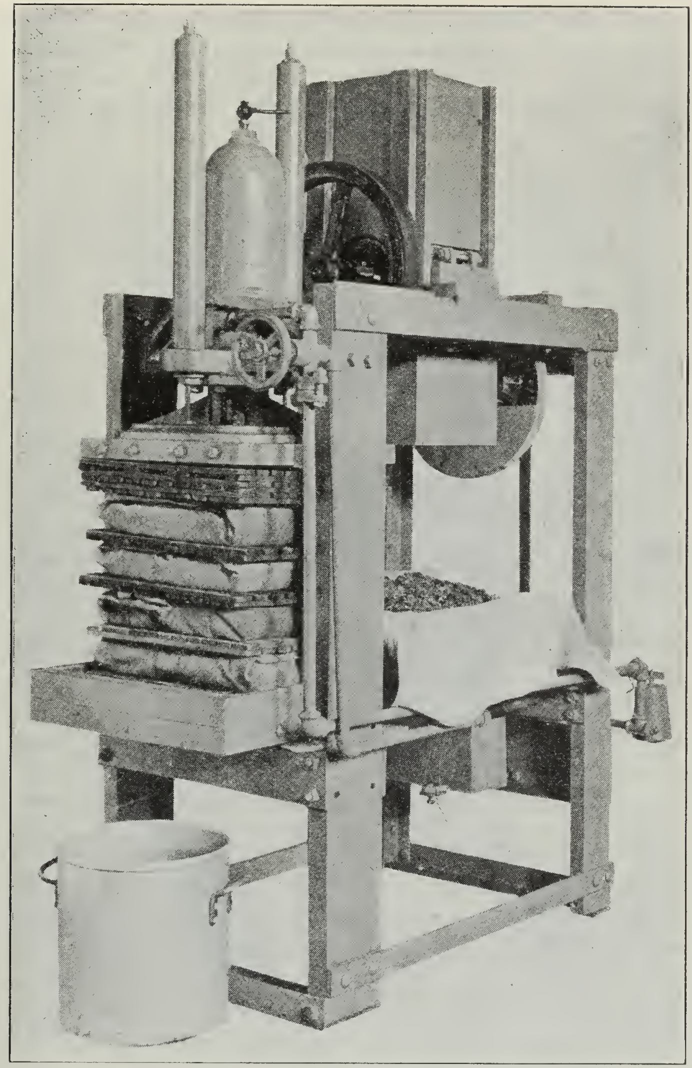

Fig. 5.—Motor-driven crusher and rack-and-cloth press.
(Courtesy of Hydraulic Press Manufacturing Co.)

a basket press without previously crushing; if crushed, too much tannin ("pucker") will be extracted.

A thorough first pressing is customary with all fruits; then empty the press cloths or basket and break up the pressed fruit with the hands or with a mechanically operated pomace breaker and press the fruit a second time. The juices from the two pressings may be combined.

More detailed directions than those given here for the operation of crushers and presses can be had from manufacturers of such equipment.

Preparing Dried Fruits for Fermentation.—Dried fruits may be pressed best after fermentation has taken place. They should be placed in open wooden

barrels or small open vats with about 50 to 60 gallons of water to each 100 pounds of fruit. Yeast is added as directed later. Fermentation ensues slowly and continues for 1 or 2 weeks. During that period the fruit must be stirred twice daily to prevent molding and souring at the surface. It can then be pressed without crushing.

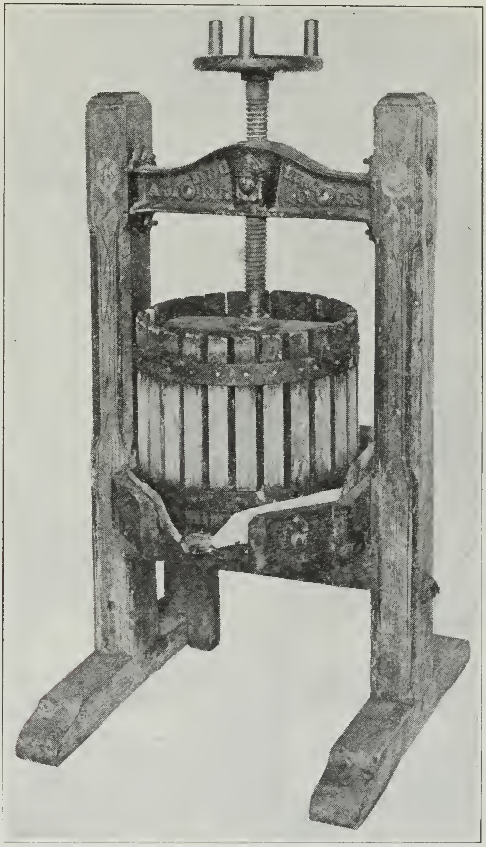

Fig. 6.—Basket press suitable for expressing juice from grapes and other soft or very juicy fruits.

Vinegar from Honey.—See subsequent section on preparation and fermentation of honey.

Barrels and Tanks.—Spruce barrels of 50-gallon capacity are economical in price and satisfactory for the farm-scale preparation of vinegar, though oak barrels are more durable. Barrels with side bungs are preferable to those with the wide bung in one end, for they may be rolled from place to place easily and provide a larger surface for acetification. If the barrels have been previously used for vinegar they should be rinsed well with water to remove mother of vinegar. They should then be filled with water in which is dissolved 2 pounds of soda ash or sal soda (sodium carbonate) for each 50-gallon barrel and allowed to stand for 3 or 4 days to neutralize the acetic acid in the wood

and thus "sweeten" the barrel. They should then be "soaked out" for several days with fresh water. It is not advisable to use barrels that have previously contained oil, spray materials, or molasses. Barrels previously used as containers for wine, alcohol, whiskey, or brandy are very satisfactory if "sweetened" before use, as described above.

For large-scale operations, redwood tanks are generally used and may be had in sizes ranging from 100 to 30,000 gallons. For farm use 500-gallon-sized tanks are preferable to the larger sizes, since they can be filled by 1 to 2 days' operation. The wood of new redwood tanks contains much coloring matter and tannin. The tanks should, therefore, be "soaked out" for a week or more with dilute soda ash or sal soda solution, about 1 pound to each 100 gallons of water, and should then be filled with fresh water changed daily for about a week.

Where barrels have become very moldy or otherwise tainted in odor they should be steamed thoroughly besides being treated with dilute soda ash or sal soda solution if they are not paraffin-lined. If paraffin-lined they should not be steamed, for the parffin will melt. Instead, they should be treated for a week with a solution of about 2 pounds of soda ash or sal soda in 50 gallons of water and then filled with cold water changed daily for a week.

Empty barrels to be stored from one season to the next will keep satisfactorily if filled with a solution consisting of 2 pounds of sodium bisulfite and 1 pint of sulfuric acid to each 100 gallons of water. Before use the following season, the barrels should be emptied and freshened by filling with cold water changed once a day for a week.

Another method of keeping barrels is to empty them and burn in each a "sulfur candle," a strip of burlap coated with sulfur. The barrels are sealed and stored indoors in a cool place. Barrels so treated become very dry and the staves loose, so that during the following season it becomes necessary to drive the hoops and "soak up" the barrels with water.

Filling the Barrels.—The barrels are filled only about three fourths full with the freshly expressed juice. They must not be filled completely or the fermenting juice will froth out of the bunghole and acetification will proceed very slowly owing to the small surface exposed to the air. The barrels may be filled beside the press and then rolled to the fermentation room ; or they may be placed in position before filling and the juice pumped to them from the press.

Effect of Brass, Iron, and Zinc.—Only wooden, hard rubber, aluminum or pressed paper (fiberboard) buckets and tubs should be used in handling juice or vinegar. The zinc on galvanized-iron equipment is dissolved by these liquids, rendering them poisonous. Glass or aluminum funnels are most satisfactory. Pumps should be made of hard rubber or of corrosion-resistant metal. Brass or iron pumps should never be used, for copper and zinc dissolved from the former will adversely affect the flavor, and iron will cause clouding and blackening of the vinegar. Throughout all operations in vinegar making, contact of the juice and vinegar with iron must be carefully avoided. It is one of the principal causes of clouding of bottled vinegars and one of the principal causes of browning.

ALCOHOLIC FERMENTATION

The following directions are given for those who may wish to use a special culture of yeast adapted to the fermentation of fruit juices:[9]

Preparation of a Starter of Pure Fruit Vinegar Yeast.—

1. Yeast as received from the laboratory is in solid form in a bottle plugged with cotton. A bottle of sterile apple juice or grape juice free of benzoate of soda should be purchased. Remove the cotton plug and fill the yeast bottle about three fourths full with sterile juice from the other bottle. Replace the cotton plug at once.

2. Leave the yeast bottle in a warm place until the juice is fermenting rapidly, as indicated by the formation of gas bubbles; 3 or 4 days' time is usually sufficient.

3. When the juice is fermenting, sterilize 3 to 5 gallons of fresh juice by heating it to boiling in a covered agateware or aluminum pot and let it cool to below 90° F.

4. Then add the contents of the yeast bottle and mix by pouring the juice back and forth a few times with a dipper sterilized by immersing in boiling water. Everything that comes in contact with the yeast or juice must be *scrupulously clean* and sterilized by boiling water or steam. Set aside in a warm place for 3 or 4 days. The juice will then be in vigorous fermentation. This quantity will be enough to start 25 to 50 gallons of juice from clean, sound fruit. When this larger quantity of juice is fermenting it may be used to start other barrels of freshly expressed juice.

Preparation of Compressed Yeast Starter.—In preparing a yeast starter with compressed yeast, break up one cake in a gallon of sterile fruit juice that has previously been brought to boiling and cooled overnight in a jar before yeast is added. Aerate by pouring back and forth, and set aside in a warm place. Within 24 hours the juice will be fermenting vigorously and can be used to inoculate a 25- or 50-gallon barrel of fresh juice. Later the fermenting juice from this barrel can be used to inoculate the contents of other barrels.

Fermentation.—To fruit juices, at least 10 per cent by volume of active starter prepared as previously described should be added as the barrels are filled. Thus, to start a 50-gallon barrel add about 5 gallons of active starter. When this barrel is actively fermenting, the juice from it may be used to inoculate other barrels of juice. These, in turn, may be used to inoculate still other barrels of juice as the crushing season progresses.

Apples, oranges, and grapes are pressed and only the juice is fermented. Peaches, figs, prunes, and some other fruits may be pressed more satisfactorily after fermentation of the whole fruit. As soon as crushed they may be placed in open fermentation vessels, such as open 50-gallon barrels. Ten per cent by volume of the yeast starter is added and mixed with the crushed fruit, which should be stirred once daily during fermentation to prevent molding and vinegar fermentation in the top of the fermenting mass. Fermentation should be allowed to proceed for 6 to 8 days. The partly fermented fruit is then pressed and fermentation allowed to continue in the expressed juice in bar-

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[9] Such a culture is available from the Berkeley Yeast Laboratory, 3219 Adeline St., Berkeley, California.

rels. Pressed apple pulp or pomace may be fermented by adding 10 per cent by volume of fermenting juice. It may then be pressed again after 5 or 6 days fermentation to yield additional juice of poorer quality. Such second-pressing pomace juice should not be mixed with that from the first pressing.

The fermentation room should be warm, that is, at or above 70° F but not above 90°. Some growers find that barrels of grape or apple juice may be stored in the sun on the south side of a building satisfactorily during fermentation unless the weather is very hot. Storage indoors, however, is usually preferable.

Duration of Fermentation.—If compressed yeast or pure fruit yeast is used as a starter in the manner already described, fermentation of apple, orange, peach, and pear juices will usually be complete in less than 2 weeks at a temperature of 70° F or above. Grape juice contains more sugar than do these other juices and, therefore, fermentation usually lasts from 3 to 4 weeks. When fermentation is complete gas is no longer given off and the juice tastes "dry," that is, free of sugar.

Use of Hydrometer to Follow Fermentation.—The course of fermentation can be followed accurately by daily readings made with a Balling or Brix hydrometer. As fermentation proceeds, the Balling degree decreases; at first slowly, then very rapidly for a few days, and finally slowly again until fermentation is complete. Grape juice when completely fermented, because of its high alcohol content, is usually about 1° Balling below 0°, and other juices are about 0° to 0.5° Balling. The instrument has been described in the section entitled "Principles of Vinegar Manufacture" (p. 3).

Storage After Fermentation.—The fermented juice should be allowed to settle for 2 or 3 weeks after alcoholic fermentation is complete. This is to rid it of yeast, pulp, and other sediment. During this settling process the tanks or barrels should be kept full to prevent the growth of wine flowers (a film yeast) on the exposed surface. This can be done by combining the liquid from one barrel with that of another. Tanks employed for storage should be closed.

Racking.—When the yeast and sediment have settled, the fermented juice must be "racked"; that is, drawn off from the sediment into other tanks or barrels. This can be done by means of a faucet near the bottom, or by syphoning with a hose from the top, or by pumping, or running by gravity into other tanks, according to conditions and equipment. The sediment may be discarded, filtered, or allowed to settle in barrels. By these methods more fermented juice may be recovered from the otherwise waste sediment.

If left in the juice, the sediment may give a bad flavor and interfere with acetic fermentation and the clearing of the vinegar.

Diluting Fermented Grape Juice.—Fermented juice of grapes grown in California is too high in alcohol content for satisfactory acetic fermentation, being on the average about 12 per cent. Water should be added to decrease the alcohol to about 8 per cent—that is, about 1 gallon of water should be added to each 2 gallons of fermented juice. *Caution:* This dilution should not be done until immediately before the fermented juice is to be acetified because on standing the diluted juice is rapidly spoiled by wine flowers and the wine-disease bacteria.

Fermentation of Honey.—Unmarketable honey may be used for making a very palatable vinegar if certain precautions are observed. Honey contains too

much sugar to ferment without dilution (chiefly invert sugar). If the honey is diluted with water, however, the minerals necessary for yeast growth are diluted to such an extent that fermentation is unsatisfactory. The material lacking, therefore, must be added. For home use, this is most readily done by the addition of fruit juice.

For manufacture on a larger scale and to prevent alteration of the characteristic color and flavor of honey by added fruit juice, the required minerals are added instead. Fabian[10] gives the following two formulas which have been found to be satisfactory:

FORMULA 1

Strained or extracted honey	40 to 45 pounds
Water	30 gallons
Potassium tartrate	2 ounces
Ammonium phosphate	2 ounces

FORMULA 2

Strained or extracted honey	40 to 45 pounds
Water	30 gallons
Ammonium chloride	4 ounces
Potassium bicarbonate	2 ounces
Sodium dihydrogen phosphate	2 ounces

The diluted honey solution should register about 15° by the Balling or Brix hydrometer. After preparation and testing, boil for 10 minutes to kill all or most of the microörganisms present that would later cause trouble, and to give a better color to the vinegar. On most farms, however, facilities for boiling the diluted honey in quantity are not at hand; but if a generous starter of compressed yeast is added, about 12 cakes for each 50 gallons of diluted honey, fermentation will usually be satisfactory. Break up the yeast in a gallon of the diluted honey and mix well with the remaining 45 to 49 gallons of liquid. Allow to ferment until "dry," that is, until it no longer tastes sweet. Then proceed with acidification as directed in the following sections, which apply to both fruit juices and honey. Fermentation of honey is slow and usually requires 5 to 8 weeks.

ACETIC FERMENTATION

Acidification before Acetic Fermentation.—The transformation of the alcohol after fermentation of the juice is brought about by vinegar bacteria. Unless the juice after alcoholic fermentation is acidified and inoculated with these bacteria there will not be enough of them to work efficiently or start quickly. These objects are both accomplished by the addition of *new* vinegar to the fermented juice after it has been racked. The fermented liquid should be acidified by at least 1 gallon of strong new vinegar to each 5 gallons of the fermented juice. This vinegar will carry with it large quantities of vinegar bacteria that will heavily inoculate the fermented juice and cause a rapid start of vinegar fermentation. After acidification and inoculation in this way, the acetic fermentation is carried out by one of the following processes.

Slow Process.—The slow process is carried out in barrels or other containers and requires from several months to a year for completion. It is greatly has-

[10] Fabian, Frederick W. Honey vinegar. Michigan Agr. Exp. Sta. Circular Bulletin 85: 1–14. 1926.

tened by the addition of vinegar as described. Barrels used should be placed on their sides and filled only about three fourths full. The top bung should be removed and the bunghole covered with a wire screen or a cheesecloth to exclude insects. At each end of the barrel, slightly above the level of the liquid two holes should be bored each about 1 inch in diameter (fig. 7). These holes should be screened also. The barrels should be kept in a warm place and not disturbed during the vinegar fermentation. The vinegar is simply allowed to remain in the barrels until it has reached its maximum strength. About three fourths of the vinegar may then be drawn off into other barrels, and an equal volume of newly fermented and settled juice may be added to the remaining one fourth of the vinegar. This new lot of fermented juice and vinegar is then

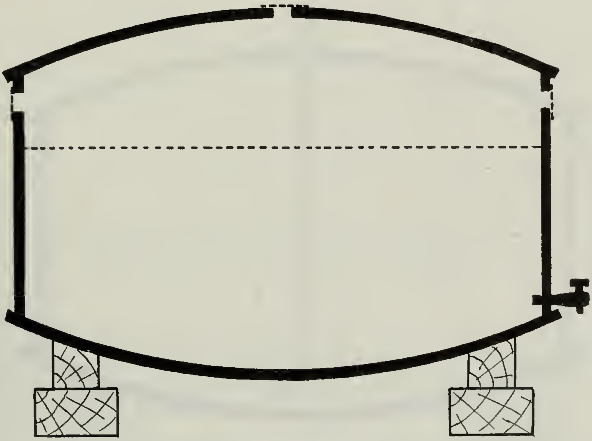

Fig. 7.—Barrel placed on its side and arranged for acetification by the slow process.

allowed to acetify. This process can be repeated indefinitely, starting the new lot of fermented juice each time with one fourth of the new vinegar left in the barrels. This method is known as the "Orleans" process and is the best of all slow processes. To allow the vinegar fermentation to depend on chance is a mistake because great risk is run of having the vinegar completely spoiled or of getting an inferior product owing to the growth of wine flowers and other undesirable organisms.

In the Orleans process it is essential that as large an area as possible be exposed for the surface growth of bacteria, that free circulation of air be insured, and that the film not be disturbed. To accomplish this it has been suggested[11] that the top bunghole be closed "with a cork through which a funnel passes, furnished at its lower end with a glass tube extending to within a few inches of the bottom of the cask. By means of this funnel new liquid can be added without disturbing the film. The lower bunghole is closed with a cork, through which passes an L-shaped glass tube which serves as indicator of level and which also can be used to draw off the vinegar" (fig. 8).

To support the desirable bacterial film and prevent its breaking and sub-

[11] Chapter on the manufacture of vinegar by F. T. Bioletti in: Marshall, C. E. Microbiology. P. Blakiston's Son and Co. Philadelphia. 1919.

merging, a light wooden grating can be floated in the liquid (as in the Claredon method) or it can be adjusted in the vinegar barrel by removing the head, supporting the grating in place, and reheading the barrel. In the Claredon process there is used a wide, shallow, covered square vat furnished with numerous openings near the top by which the entrance of air can be facilitated and regulated. Each acetifying vat is connected with a small measuring vat from which the proper amount of liquid is added after a corresponding amount of vinegar has been removed.

Upright-Generator Process.—The rate of vinegar fermentation depends upon the amount of air supplied to the vinegar bacteria. Vinegar generators merely increase the amount of vinegar surface exposed to the air. The surface

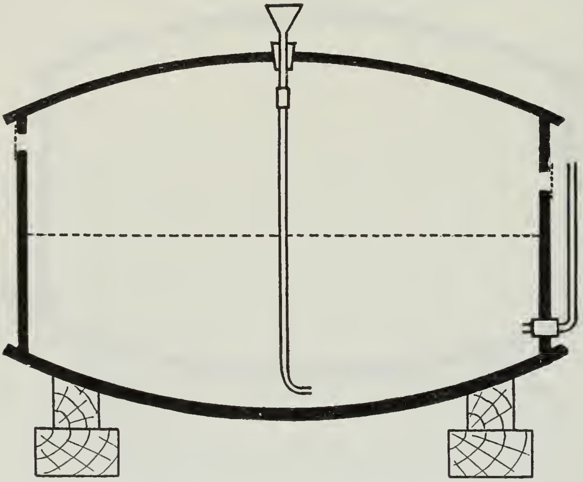

Fig. 8.—Barrel arranged with funnel and glass tube for the introduction of new liquid for acetification without disturbing the film of vinegar bacteria, and with glass tube indicating level. (After F. T. Bioletti.)

is a great many times that which would be exposed in an ordinary barrel. Therefore, the rate of acetic fermentation is correspondingly increased. Most generators consist of an upright tower filled with beechwood shavings, rattan shavings, corncobs, coarse coke, charcoal, or other suitable material through which the liquid slowly percolates. Beechwood shavings are preferable for fruit juices. Successful operation of vinegar generators requires considerable experience and skill. The investment required is rather heavy. Unless properly and continuously operated, generators become diseased and cease to deliver vinegar. For these reasons the generator process is not recommended for farm use. All things considered, the Orleans slow process is to be preferred to other processes for the farm-scale manufacture of vinegar.

Rolling-Generator Process.—The so-called "rolling generator" greatly shortens the time required for acetification and approaches in speed the commercial process of making vinegar in upright generators. This plan requires more work and attention than the slow method, but by providing for a greater circulation of air it greatly hastens acetic fermentation.

An ordinary vinegar barrel is made into a generator as follows:[12]

After one head of the barrel has been removed, a small rack is built into the barrel in such a way as to make throughout its length, about 6 inches below the bunghole, a compartment which is to be filled with beechwood shavings or corncobs. A quick way to do this is to make a rack of slats 3 inches wide by one-half inch thick, set into grooved end pieces, with about one-half inch of space between them. At each end this rack is supported by a 2 by 4 inch piece cut in such lengths that the rack will be at least 6 inches below the bung. The 2 by 4's are usually joined at the bottom by a crosspiece 1 by 2 inches. After this rack is set in place and the compartment is filled with cobs or shavings, the barrel is reheaded and three 1-inch holes are bored obliquely downward in each end so that the openings come just beneath the bottom of the rack holding the shavings or corncobs. In constructing the rack and fastening it to the 2 by 4's, grooves or dowels should be used, or, if more convenient, the rack may be held together by hardwood pegs. Iron or other metallic nails should not enter into the construction.

When used for the first time or after it has been standing idle for any length of time, the generator should be thoroughly scalded with hot water or steam. After the generator has been completely drained, about 1 gallon of fresh unpasteurized vinegar is poured into it. All the holes are tightly plugged, and the generator is turned to allow the vinegar to run over and saturate the shavings. The generator should then be filled about half full with yeast-fermented juice. Several times each day, if possible, but at least once a day, all the holes should be closed with wooden pegs and the generator rolled over, so that the bung is at the bottom, and shaken three or four times to bring the juice thoroughly in contact with the beechwood shavings or corncobs. The generator is then rolled back into its original position and the wooden pegs are replaced by cotton plugs. As there is a circulation of air from the end holes through the shavings out of the bunghole, the juice dripping from the shavings comes in contact with the air, as a result of which the process of acetification is greatly hastened.

As the fermentation progresses, a good deal of heat is developed. To obtain the best results the temperature of the upper portion of the generator should be kept at about 85° F. The temperature can be lowered by inserting some of the pegs to cut down the air current passing through the holes. To raise the temperature the supply of air is increased by removing some of the pegs.

If the generator is rolled every day and the temperature is maintained at from 80° to 85° F the fermented juice may be converted into good vinegar by this method in 60 to 90 days.

Loss of Acid by Prolonged Fermentation.—After all the alcohol present is converted into acetic acid by any method of acetification, the vinegar bacteria then attack the acid itself and cause a rapid decrease of the total acidity, in the presence of air. In time all the acid is destroyed and the vinegar ruined. This destruction can be prevented by filling the barrels completely after the acetification is complete and then sealing them tightly.

For the best results, therefore, occasionally determine the acid content of the fermented juice in each barrel, and when the acidity no longer increases, combine the contents of two or more barrels to give full containers and then seal them to exclude air. For methods of analysis see section "Determination of Total Acidity" (p. 20).

Aging.—When the vinegar has reached its maximum strength either by the slow or by the generator process, it must be aged before it is at its best quality for table use. The aging process, which takes place during storage, improves the flavor and clearness. The best vinegar is aged at least a year before it is put on the market. The aging should take place in tanks or in barrels that are kept full and closed, so that destruction of acid by oxidation by the vinegar bacteria will not occur.

[12] LeFevre, Edwin. Making vinegar in the home and on the farm. U. S. Dept. Agr. Farmers' Bul. 1424:1–28. 1924.

Flavoring Honey Vinegar.—Honey vinegar is improved by adding a small amount of tarragon herb; or if this is not obtainable from the local grocer or druggist, a small quantity of fennel seed or dill herb may be used. Leave in the vinegar for about 2 weeks.

CLARIFICATION AND FILTRATION

Well-made vinegar from good material will very often clear sufficiently during the aging process to make it suitable for bottling. Usually, however, the clearing must be done by filtration or by fining, that is, by adding some clarifying substance. Filtration is to be preferred to fining because the results are more certain.

Fining.—Two substances in common use for the fining of vinegar are fish isinglass and clay products such as Bentonite and Spanish clay. Isinglass is the more expensive and more difficult to use, but produces more nearly perfect clearness when the treatment is successful. The usual amount of isinglass necessary to clarify cider vinegar is about 1 ounce for each 100 gallons, although this will vary considerably with the condition of the vinegar. It should be added as a solution prepared as follows: 1 ounce of isinglass is broken up into small pieces, mixed with 1 gallon of vinegar, and allowed to soak until it becomes swollen and soft. Warming the mixture hastens the process. The softened isinglass is then broken up thoroughly and mixed with the vinegar until a solution free from lumps is obtained by passing through a fine sieve and breaking up the lumps that are retained. This isinglass solution is then added to the vinegar at the rate of 1 gallon for each 100 gallons of vinegar to be clarified. The vinegar and isinglass are then mixed thoroughly in a barrel or tank by stirring. The mixture is allowed to stand until the isinglass settles leaving a clear liquid above. The clear vinegar can then be drawn off with a hose or from a faucet. The sediment can be drained off and filtered. Some vinegars do not respond to this treatment and remain cloudy. In such cases filtration must be resorted to; or Spanish clay or Bentonite added as directed in the following paragraph.

Spanish clay and Bentonite are used as follows: The clay or Bentonite is mixed with water at the rate of ½ pound to each gallon of water, and allowed to soak for several days until it becomes soft. It is then worked up with the hands or by continuous agitation to give a thin, smooth mud or suspension of clay. For each 100 gallons of vinegar to be clarified from 2 to 8 gallons of the clay "solution" (suspension) is used. Considerably less Bentonite is required; usually not more than 1 gallon to 100 gallons. This "solution" is mixed with the vinegar by stirring and is allowed to settle in the same way as directed for isinglass.

The amount of material to be used will vary with the cloudiness and the condition of the vinegar. Where an attempted isinglass clarification has failed the vinegar may later be treated successfully with Bentonite, or often they may be added together with good results.

Filtration.—Where large quantities of vinegar are to be made, clarifying often becomes impracticable, and filtration is employed because of its cheapness and because very large volumes can be handled rapidly. Any of the standard types of filters can be used successfully for vinegar if the interior of

the filter is heavily coated with tin to protect it from the action of the acid, or if it is made of corrosion-resistant material such as hard rubber. For small-scale operations, a cloth-bag filter costing $5 to $10 may be used. For farm-scale use, conical bags made of heavy duck cloth (14-ounce duck) and holding about 10 gallons each may be used. Add about ¼ pound of Filter-Cel to each 10 gallons of vinegar just before adding vinegar to the filter and stir well as it is added. Use only *wooden, aluminum, hard rubber, or pressed paper buckets and tubs* in handling vinegar.

BOTTLING AND PASTEURIZATION

Bottling.—For bottling purposes vinegar should be aged and perfectly bright. If the operations previously described have been carried out successfully, the vinegar will be in this condition. Bottles should be filled full and well corked so that bacteria will not grow in the vinegar and cause it to become cloudy. Clouding by vinegar bacteria can be prevented by adding 1½ ounces of sodium bisulfite per 50 gallons. Ordinary grape-juice bottles or other type of crown-cap bottles[13] make very satisfactory containers for vinegar, because the capping is less expensive and troublesome than corking, and the appearance is attractive.

Pasteurization.—Heating the bottled vinegar to not less than 140° F and not more than 160° will check the growth of vinegar bacteria. This preserves the vinegar and maintains its strength and also gives it a smoother or more pleasing taste and aroma when it matures.

The bottled vinegar may be pasteurized by heating the bottles in water in a tank or tub to a temperature of from 140° F to 150° F until the contents of the bottles reach 140° F. This requires about 30 minutes at 140° to 150° F. This method of pasteurization is discussed more fully in Circular 313[14] and Extension Circular 65.[15] Pasteurization also may be accomplished by heating the vinegar in bulk to 140° F, cooling to 70° F, and then bottling. Pasteurization is usually not practiced except in large factory-scale operations. It is usually dispensed with in the farm-scale manufacture.

COMMON CAUSES OF SPOILING

Lactic-Acid Bacteria.—Fermented fruit juices that have not been fermented with pure yeast usually develop lactic-acid bacteria. These bacteria, also known as "tourne bacteria," are very common in naturally fermented juices. They produce a disagreeable taste, cloudiness, as well as lactic and other acids. These persist in the vinegar and lower its quality. The lactic-acid bacteria can be avoided if a yeast starter is used and if the fermented juice is mixed with 10 to 25 per cent of vinegar as soon as the alcoholic fermentation is complete. The acetic acid arrests the growth of these bacteria.

Wine Flowers.—If the fermented fruit juice is left in open tanks it will become coated with wine flowers, a form of film yeast that destroys alcohol

[13] Some of the materials in this circular, such as crown caps, may become scarce or unavailable for civilian use because of the war. If the reader finds that some of these are unavailable, he will naturally do the best he can with substitutes.

[14] Irish, J. H. Fruit juices and fruit juice beverages. California Agr. Exp. Sta. Cir. 313: 1–62. 1932. (Out of print.)

[15] Cruess, W. V. Home preparation of fruit juices. California Agr. Ext. Cir. 65:1–15. 1932.

and flavor, and causes cloudiness. It can be avoided by storing the fermented juice in filled and closed barrels or tanks, or by addition of 1 gallon of new vinegar to each 3 gallons of fermented juice, as directed under vinegar fermentation.

Vinegar Eels.—Vinegar often becomes infested with small nematode worms known as "vinegar eels." These are about 1/8 inch long and can be seen by holding the vinegar in a glass to the light. They destroy the acid and are very unpleasant in appearance. If the fermented juice or vinegar in the factory becomes badly infested, all the juice and all the tanks must be sterilized by heat to rid the factory of them. Vinegar infested with eels can be sterilized by heating to about 130° F, at which temperature they are killed. Tanks and barrels should be sterilized by steam. The same applies to generators, which often become contaminated with this pest. A sterilizer can be made by surrounding a piece of tin pipe, 10 feet or more in length, with a steam jacket made of iron pipe. The vinegar or fermented juice is passed through the tin pipe, which is heated by steam. The hot vinegar or fermented juice can be cooled by passing it through a second coil of tin pipe immersed in water.

Filtration after a heavy addition of Filter-Cel will remove the eels from vinegar to be bottled. This is perhaps the most practicable method of eliminating them from vinegar made on a farm scale.

DETERMINATION OF TOTAL ACIDITY

Vinegar offered for sale must contain at least 4.0 per cent acetic acid. In addition it usually contains about 0.5 per cent of acid other than acetic. The acidity of vinegar is expressed as "total acid as acetic acid." On this basis a vinegar containing 4.0 per cent acetic acid would show about 4.5 per cent total acid, expressed as acetic. Labels on bottles of cider vinegar often bear the words "diluted to 45-grain strength"; meaning that it has been diluted to 4.5 per cent total acid content, since 45 grains is equivalent to 4.5 per cent.

Determination of acetic acid is difficult and requires elaborate apparatus, and training in analytical experience. Determination of total acid, however, is not difficult and the apparatus required is inexpensive.

Everyone who manufactures vinegar for sale should be equipped to make this simple determination, because he can thus make certain that his vinegar contains at least the legal minimum concentration of acid. Occasional acid determinations are also essential in deciding whether acetic acid fermentation is progressing properly and when maximum acid has been reached. This will indicate when to pasteurize to check the growth of vinegar bacteria; for, as previously stated, the bacteria eventually attack and destroy the acid they have formed.

Determination by Titration.—The most accurate method of determining the total acid content of vinegar is by titration. The following apparatus and reagents are required (fig. 9):

(1) One or more 10-cc pipettes. It is advisable to secure several so as to provide a reserve for breakage.

(2) One 50-cc burette with glass tip, rubber connection for tip, and pinch clamp. The burette should be graduated in 1/10-cc divisions.

(3) An iron ring stand about 18 inches high for use as a burette stand.

(4) A clamp to attach the burette to the ring stand.

(5) Several 6-ounce glass tumblers.

(6) Several 6-inch pieces of solid-glass tubing about 1/8 inch in diameter for use as stirring rods.

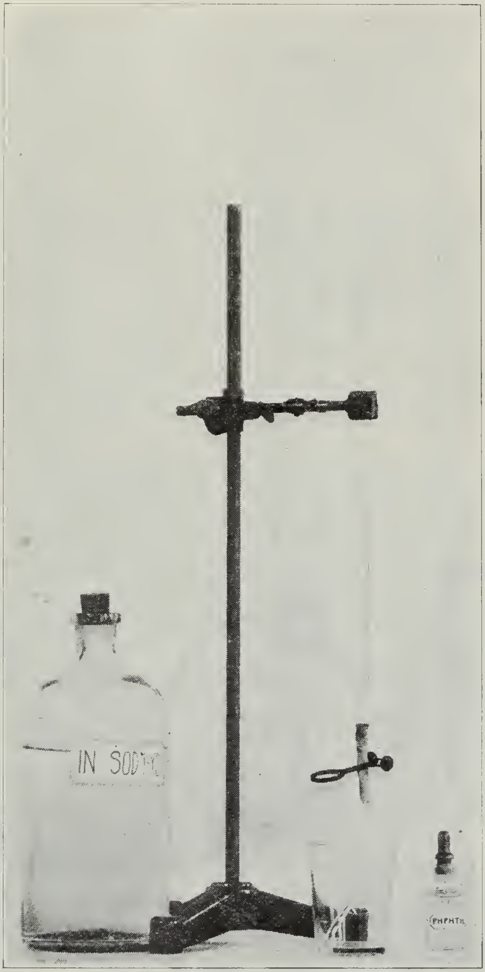

Fig. 9.—Apparatus and reagents used in titrating the total acidity of vinegar.

(7) A dropping bottle filled with 0.5 per cent phenolphthalein dissolved in alcohol; this is the indicator solution.

(8) Normal, that is N/1 or 1N, standard sodium hydroxide solution.

(9) Distilled water, about a gallon.

To conduct an acid determination proceed as follows:

(*a*) Rinse a 10-cc pipette with the vinegar to be analyzed. Place the upper end (broad end) of the pipette in the mouth and by sucking fill the pipette. Quickly place a finger over the upper end of the pipette; and by partly re-

leasing the pressure allow the level of the vinegar to drop slowly, exactly to the line engraved on the stem. This is the 10-cc mark. Then allow the 10 cc of vinegar to flow into a clean tumbler.

(*b*) Add about 30 or 40 cc of distilled water, that is, 3 or 4 times as much distilled water as there is vinegar in the tumbler.

(*c*) Add 3 or 4 drops of the phenolphthalein indicator.

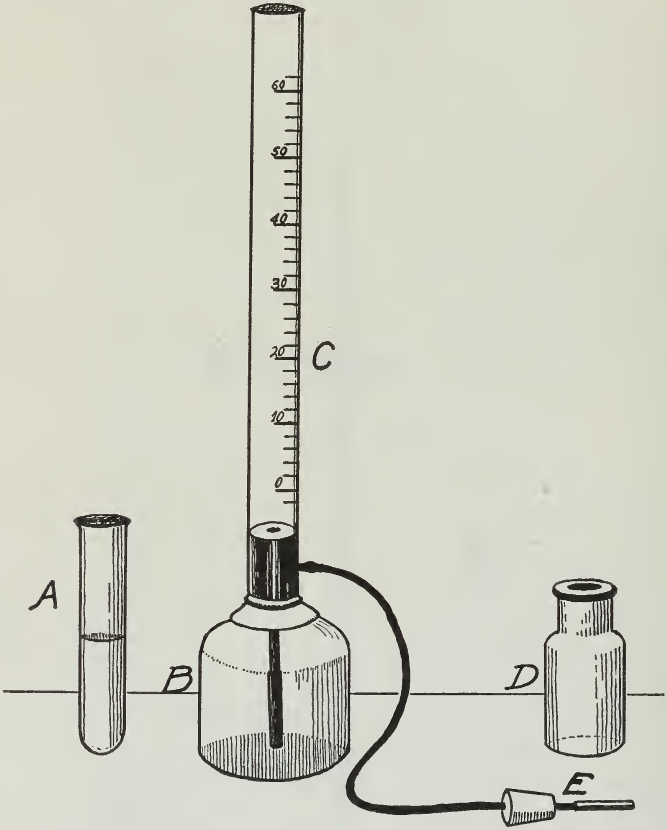

Fig. 10.—Leo acidimeter. *A*, Tube for measuring vinegar sample; *D*, bottle in which vinegar and soda react; *E*, scoop for measuring soda, attached to cork fitting *D*, and connected by rubber tubing to *B*; *B*, water reservoir; and *C*, graduated cylinder.

(*d*) Fill the burette with standard normal sodium hydroxide solution and read the level of the liquid.

(*e*) Add the sodium hydroxide solution slowly from the burette to the tumbler, stirring with a glass rod, until, finally, one drop causes the color of all of the liquid in the tumbler to remain pink. The pink color should last for at least a minute. This operation is spoken of as "titration."

(*f*) Now take a reading of the level of the liquid in the burette.

(*g*) Multiply the number of cc of sodium hydroxide used by 0.6. The result is the total acid content of the vinegar in grams per 100 cc. Multiply this value by 10 to get grain strength.

Example: First reading of burette = 2.1 cc (before titration); second reading = 10.6 cc (at end of titration). The difference is $10.6 - 2.1 = 8.5$ cc, the volume of sodium hydroxide actually used. Then, $8.5 \times 0.6 = 5.10$ grams total acid per 100 cc; or $5.1 \times 10 = 51$-grain strength.

Determination by the Vinegar Tester (Leo Acidimeter).—The vinegar tester illustrated in figure 10 is more easily used than the titration method and the results obtained are sufficiently accurate for factory use. Its operation depends on the principle of evolving carbon dioxide gas from sodium bicarbonate by action of the acid of the vinegar. The volume of gas evolved varies with the strength of the vinegar. The apparatus measures this volume. The procedure is as follows:

(*a*) Rinse the small test tube *A* with a little vinegar (do not rinse with water for the water remaining in the tube would dilute the sample). Then fill this tube with vinegar exactly to the engraved line (graduation mark) and pour into the small bottle, *D*. Bottle *B* has previously been filled with water. At this time *C* must contain *no water*.

(*b*) Fill the scoop E with sodium bicarbonate (ordinary baking soda).

(*c*) Hold bottle *D* almost horizontal and insert the scoop *E* and cork in such manner that none of the soda drops into the vinegar until the cork is forced tightly into bottle *D*.

(*d*) Force the cork tightly into place. Shake soda off *E* into the vinegar and shake bottle *D* until the water rises no further in the glass tube *C*—usually about 2 minutes. The gas evolved in *D* forces the water to rise in *C*.

(*e*) Read the grain strength at the level of the liquid in *C*. Divide by 10 to get corresponding grams acid per 100 cc.

(*f*) Open and thoroughly rinse bottle *D* with water before making another analysis.

The following precautions are necessary: (1) do not allow any of the soda to come in contact with the vinegar before the cork is tightly in place. (2) Rinse bottle *D* thoroughly with water, 3 or 4 rinsings, before adding a vinegar sample to it. *Do not rinse it with vinegar; rinse it only with water.* (3) There must be no leaks. The cork must fit tightly in *D* and the rubber tubing must be free of leaks. (4) Do not take the reading too soon; shake flask *D* until the water rises no further in *C*. (5) On very hot days the reading will be somewhat too high owing to expansion of the gas; on very cold days it will be too low. The ideal temperature is about 65° to 70° F.

This instrument is sold by chemical supply houses and vinegar equipment companies as the Leo acidimeter.

PUBLICATIONS ON VINEGAR

Articles of interest to the prospective manufacturer often appear in trade journals such as *The Fruit Products Journal and American Vinegar Industry,* published monthly by the Avi Publishing Company, 31 Union Square, New York, N. Y. The following readily available references are recommended for supplementary reading:

LEFEVRE, EDWIN.
1924. Making vinegar in the home and on the farm. U. S. Dept. Agr. Farmers' Bul. **1424:** 1–28.

HYDRAULIC PRESS MANUFACTURING COMPANY.
1919. The vinegar hand book. Publication No. 83. 64 p. Published at Mount Gilead, Ohio. (This gives a good description of the generator process.)

MARSHALL, C. E.
1919. Microbiology. P. Blakiston's Son and Co., Philadelphia, Pa. p. 538–50.

PARTIAL LIST OF DEALERS CARRYING EQUIPMENT FOR THE MANUFACTURE OF VINEGAR

Valley Foundry and Machine Works, Fresno, California. (Crushers, presses, and filters.)

Food Machinery Corporation, San Jose, California. (Crushers, presses, shavings, filters, and vinegar-testing equipment.)

Braun-Knecht-Heimann Company, San Francisco, California. (Vinegar-testing equipment; clarifying agents such as fish isinglass, Bentonite, etc.)

Braun Corporation, Los Angeles, California. (Vinegar-testing equipment and clarifying agents.)

Hydraulic Press Manufacturing Co., Mt. Gilead, Ohio. (Crushers, presses, filters, and vinegar-testing equipment.)

Marshall Dill, San Francisco, California. (Filters, bottling equipment, bisulfite, Bentonite, etc.)

Johns-Manville Co., San Francisco, California. (Filter-Cel and other filter aids.)

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